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female caste has been abolished and its reproductive function transferred to gynaecoid workers, i.e., to forms differing from ordinary workers only in their ability to produce worker as well as male offspring. It is very probable that even this abolition of whole casts has been accomplished by very slow and gradual processes and not by sudden variations, or mutations.

- <sup>1</sup> Wheeler, *The Ants of the Baltic Amber*, *Königsberg Schr. physik. Ges.*, 55, 1914, (1-142).
- <sup>2</sup> *Zool. Jahrb. Abth. Syst.*, Jena, 8, 1895, (774).
- <sup>3</sup> *Die Fossilen Insekten*, Leipzig, 1908, (p. 1283).
- <sup>4</sup> *Loc. cit.*, (p. 1285).
- <sup>5</sup> *Bull. Geol. Soc. Amer.*, 20, 1910, (427-606), and *Climates of Geologic Time*, *Carnegie Inst. Washington Pub.* No. 192, (pp. 263-298).
- <sup>6</sup> Dewitz, *Zs. wiss. Zool.*, Leipzig, 30, 1878, (78-105), Pl. 5.
- <sup>7</sup> *British Ants*, 1915, (p. 131 and 221), Fig. 50.
- <sup>8</sup> *Bull. Amer. Mus. Nat. Hist.*, New York, 21, 1905, (405-408), 1 pl.; *Ants, etc.*, 1910, (p. 99), Fig. 63.
- <sup>9</sup> *Rev. Suisse Zool.*, 10, 1902, (444).
- <sup>10</sup> *Ibid.*, 18, 1910, (27).
- <sup>11</sup> *Ark. Zool.*, 9, 1915, (71).
- <sup>12</sup> *Biol. Bull.*, 4, Woods Hole, Mass., 1903, (180).
- <sup>13</sup> *Acta Soc. Ent. Bohemica*, 5, 1908, (139-146), 4 figs.
- <sup>14</sup> *British Ants* 1915, (p. 220), Fig. 47.
- <sup>15</sup> *J. Exper. Zool.*, 8, 1910, (421), Fig. 7.
- <sup>16</sup> *Zs. wiss. Zool.*, 114, 1915, contains a full bibliography of the author's papers on the Lomechusini.
- <sup>17</sup> Wheeler, *Boston, Proc. Amer. Acad. Arts Sci.*, 51, 1915, (257).
- <sup>18</sup> Arnold, *Ann. S. Afric. Mus.*, 14, 1916 (195).

## REFRACTIVITY DETERMINED IRRESPECTIVE OF FORM, BY DISPLACEMENT INTERFEROMETRY

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*1. Introductory.*—Some time ago<sup>2</sup> I made a number of experiments on the use of curilinear compensators in connection with the displacement interferometer. It is obvious that the curvature in such a case must be very small, so that single lenses for the purpose are not easily obtained. The use of a doublet of two lenses of the same glass but respectively convex and concave, meets the case fairly well, the necessary refracting power being obtained by spacing the doublet. Lenses of about one diopter each gave the best results, bringing out fringes of quasi-elliptic and hyperbolic symmetry in great variety.

Later it appeared as if plates of different varieties of glass, as for instance crown and flint, if placed in the two interfering beams would

produce the same phenomena. The flint plate used, however, proved to be inadequately plane, so that the result is in doubt.

More recently I have endeavored to secure similar results by submerging the lens (convex or concave) in a liquid of about the same index of refraction. This method would seem to be interesting in other respects; for it is probable that the index of the solid may be determined in this way irrespective of form.<sup>3</sup> If for instance the liquid and the solid have the same index, one would be tempted to infer that the latter may be removed or inserted, without displacing the center of ellipses at the particular wave length under consideration. The index of the liquid in place is then also determinable by the interferometer, to a few units in the fourth place. Unfortunately the problem is not so simple.

If experiments of the present kind are to be accurate, it is obvious that the walls and cavity of the trough in which the lenses are to be submerged must be *optically* plane-parallel. Otherwise some compensating adjustment must be made at the opaque mirrors of the interferometer and for this no adequate allowance can be made. It did not however seem worth while to provide expensive apparatus, before the method had been worked out in detail. Accordingly the present experiments were conducted with troughs of ordinary plate glass put together by myself, and little attention was given to absolute values of index of refraction, as such.

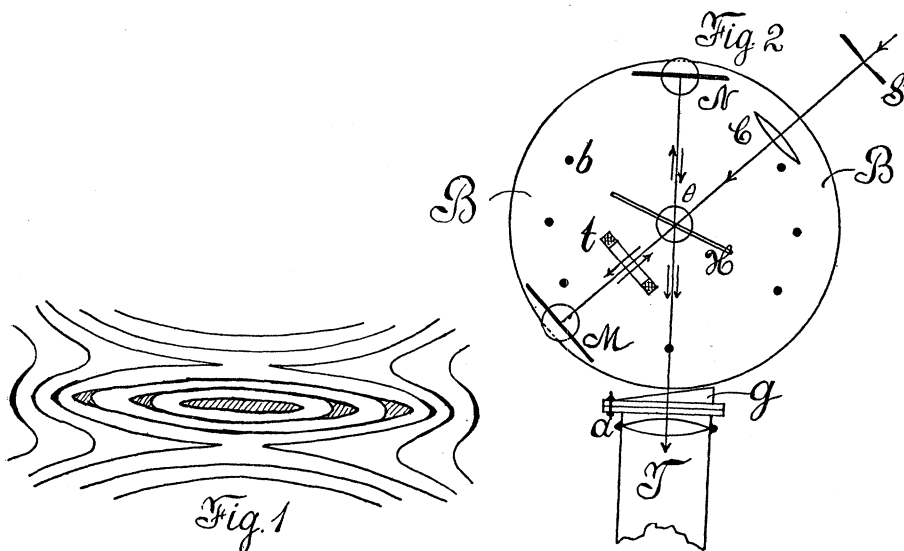
2. *Preliminary experiments.*—The first experiments were made on a large linear interferometer with distances of nearly 2 meters between the mirrors. The rays in such a case are all very nearly parallel. Sunlight, arc light or the Nernst filament were each available for illumination. With a very long collimator (2 meters) and wide single lens objective (10 cm. or more), the Nernst filament may be used directly in place of the slit.

On inserting the trough with a thickness of 1.3 cm. of CS<sub>2</sub> solution normally into one component beam, the original very large ellipses were reduced in size and rounded as usual to smaller circles. Submerging a convex lens (1 diopter) into the liquid until the beam passed symmetrically through it, changed these circles to very long horizontal spindles. A concave lens similarly produced horizontally very eccentric hyperbolae. All these fringes lie considerably in front of the principal focal plane of the telescope and the abnormal forms are necessarily relatively faint. They change in shape and intensity with the focal plane observed.

On mixing CS<sub>2</sub> with kerosene (about equal parts) types of fringes shown in figure 1, but with many more lines, were obtained. This is

a combination of both spindles and hyperbolae. Probably three layers of liquid are chiefly in question, viz., kerosene, kerosene +  $\text{CS}_2$ ,  $\text{CS}_2$ , and the three stages of form and the sinuous lines correspond to them. Fringes were sharp only if viewed in front of the principal focal plane of the telescope.

3. *Apparatus*.—To obviate the tremor of apparatus which is inevitable in the case of the long distance interferometer, the parts were now screwed down at short distances in the cast iron block *B* figure 2. Here the ranges *MH*, *HN* of half silvered plate, *H*, and opaque mirrors *M*, *N*, did not exceed 14 cm., but this gives ample room for the manipulation of the trough *t* placed normally in the beam *MH*. White light en-



ters by way of the collimator *SC* at any convenient angle  $\theta$  (as this does not occur in the equations) and  $\theta = 60^\circ$  was used. The opaque mirrors *M* (and preferably also *N*) are on micrometers with screws normal to their faces and each must be provided with adjusting screws relatively to horizontal and vertical axes. An elastic fine adjustment (not shown) is desirable. The block contains a number of screw sockets, *b*, for attaching subsidiary apparatus. The trough, *t*, should preferably be attached to an independent supporting arm, not connected with *B* and be revolvable about two axes normal to each other. In such a case the position *normal* to the beam of light may be found from the reverse of motion of the interference rings, while the trough is slowly rotated in a given sense.

The telescope  $T$  (relatively much enlarged in the diagram) is not attached to the block. It is to be used both as a simple telescope for the adjustment of the white slit images to horizontal and vertical coincidence, and as a direct vision spectroscope. The most convenient attachment for this purpose is the direct vision prism grating,  $G$  (film grating), just in front of the objective of  $T$ . Two perforated thin discs of brass are useful for this purpose, one disc being firmly attached (like the cap) to the objective, the other to the flat face of the grating with the prism outward. A swivel bolt,  $a$ , between the discs, thus allows the observer to throw out the grating and use the telescope. A stop arrests the motion of the grating when it is rotated about  $a$ , back again, for viewing the spectrum. This plan worked very well and the ellipses obtained were magnificent. It was now almost possible to control the micrometer  $M$  manually and all hurtful quiver is absent. The fiducial line to which centers of ellipses, etc., are to be returned is always the sodium doublet, present in sunlight or the arc and artificially supplied by an interposed burner in case of the Nernst lamp. The telescopic lens need not be more than 2 cm. wide and cross hairs are not needed. For measuring dispersion the Fraunhofer lines B, C, D, E, b, F, were used.

4. *Equations.* The useful equation for present purposes are given in a preceding report<sup>4</sup> and the following cases only need be repeated here. If  $e$  is the thickness of glass plate of index of refraction  $\omega$  for the wave length  $\lambda$  and if the equation  $\mu = A + B/\lambda^2$  where  $A$  and  $B$  are constants be taken as sufficient

$$\mu - 1 = \Delta N/e - 2 B/\lambda^2, \quad (1)$$

where  $\Delta N$  is the displacement of the micrometer at the opaque mirror  $M$  or  $N$  due to the insertion of the plate normally to the component beam in question. To determine  $\mu$ ,  $B$  must be known at least approximately. It may be measured in the same adjustment, however, if two Fraunhofer lines are used fiducially. Let  $\delta N$  be the displacement of micrometer to pass the center of ellipses from wavelengths  $\lambda$  to  $\lambda'$ . Then if  $e'$  is the thickness of the half silvered plate  $H$ , and  $R$  the angle of refraction within it,

$$\delta N = B \left( e + e' \cos R + 2 \left( e + \frac{e'}{\cos R} \right) \right) \left( \frac{1}{\lambda^2} - \frac{1}{\lambda'^2} \right), \quad (2)$$

If  $e = 0$ ,

$$\delta N_a = B \left( e' \cos R + \frac{2 e'}{\cos R} \right) \left( \frac{1}{\lambda^2} - \frac{1}{\lambda'^2} \right) \quad (3)$$

which may be called the corresponding air displacement. Hence

$$B = \frac{\delta N - \delta N_a}{3e \left( \frac{1}{\lambda^2} - \frac{1}{\lambda'^2} \right)} \quad (4)$$

Here  $\delta N = \delta N_a = N - N' - (N_a - N'_a) = N - N_a - (N' - N'_a)$

so that the difference of the corresponding positions of micrometer for a given Fraunhofer line, with and without the plate, are to be found. The method is quite accurate as will be seen below. More than two constants  $A$  and  $B$  may be taken if desirable, with 3 Fraunhofer lines.

To return to equation (1), remembering that  $2B/\lambda_2$  is small, it is seen that the percentage accuracy of  $\mu - 1$  and  $\Delta N$  are nearly equal. Now  $\Delta N$  for a plate 5 to 6 mm. thick and ordinary glass is about 0.3 cm. This may be measured within  $10^{-4}$  cm. or 3 parts in  $10^4$  of  $\Delta N$  or one or two units in the fourth place of  $\mu$  the index of refraction of the glass. A much more serious consideration is the consistent measurement of the *thickness* of plate  $e$ , which must be given to less than  $10^{-4}$  cm. if the same accuracy is wanted. Naturally this presupposes optic plate. Hence the data will be inaccurate as to absolute values from this cause. The plates used frequently showed increases of thickness of several  $10^{-3}$  cm. within a decimeter of length. Absolute values were however without interest in this paper.

To show that less than  $10^{-4}$  cm. is guaranteed on the micrometer in the placing of elliptic centers at the sodium line, the following pairs of results, made at different times and with entirely independent adjustments may be cited. The screw pitch was 0.025 cm. and the drum divided into 50 parts with a vernier to 0.1 part.

FRAUNHOFER LINE	PITCH	DRUM	PITCH	DRUM	DIFFERENCE
					<i>cm.</i>
B.....	×85	17.1	74	33.2	0.25000+0.01695
C.....	×85	23.3	74	39.3	0.25000+0.01700
D.....	×85	41.0	75	7.0	0.25000+0.01700
E.....	××86	14.9	75	30.9	0.25000+0.01700
b.....	××86	19.2	75	35.2	0.25000+0.01703
F.....	×××86	36.6	76	2.6	0.25000+0.01703

× ellipses long horizontally ×× circles ××× ellipses long vertically.

The total difference is less than  $10^{-4}$  cm. and probably due to the width of the Fraunhofer lines with deficiency of light at the ends of the spectrum. Apart from the measurement of the thickness  $e$  therefore, the method is guaranteed for fourth place work.

A large number of experiments were made with lenses, etc., submerged in mercury iodide solution, data for which there is no room here. The curious result appeared that if the solution refracts more strongly than the submerged glass, and the lens is well centered as to the beam of light, the ellipses remain strong and clear. Hence the refraction of the solution and of the glass need not be identical. The dispersion  $B$  is particularly well determinable. The refraction at  $\lambda$  in this case will be subject to

$$K' = \mu' - 1 + 2B'/\lambda^2 = \mu - 1 + 2B/\lambda^2 + \Delta N/e$$

when  $\Delta N$  is the displacement produced on submerging the lens of thickness  $e$  at its middle and primes refer to the solution. The following is an example of results.  $K'$  for the solution is found as a whole from the full and empty trough.

Lens	$e$ cm.	$K'$	$\Delta N$ cm.	$\mu$	
1 diopter.....	0.138	0.6140	0.0078	1.5315	Ellipses strong
2 diopters.....	0.200	0.6140	0.0107	1.5345	Ellipses strong
5 diopters.....	0.248	0.6140	0.0187	1.5126	Ellipses faint
10 diopters.....	0.447	0.6343	0.0205	1.5625	Ellipses vague

The first two cases are good, the last two untrustworthy. To perfect this method a solution must be found whose dispersion constants are not so enormous compared with glass as the mercury iodide solution.

<sup>1</sup> Note from a Report to the Carnegie Inst. of Washington.

<sup>2</sup> *Washington, Carnegie Inst., Pub.*, No. 249, 1916, chap. ix, cf. *Amer. J. Sci., New Haven*, 40, 1915, (299-308).

<sup>3</sup> Mr. R. W. Cheshire, *Phil. Mag., London*, 32, 1916, (409-420), has recently used Töpler's method for the same purpose with marked success.

<sup>4</sup> *Washington, Carnegie Inst., Pub.*, No. 229, 1915, § 40, 41, 42.

## THE FOOD OF DROSOPHILA MELANOGASTER MEIGEN

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Communicated by W. M. Wheeler, December 26, 1916

In May, 1916, while rearing the banana fly on artificial media of fermented banana agar,<sup>1</sup> I observed that visible fungus growths seldom occurred in the presence of many larvae. Such growths did appear, however, after pupation or if only a few larvae were present. Examination showed the surface growths to be largely yeast cells.

Further investigation showed that adult flies, pupae, larvae, and eggs